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<p>(21) International Application Number: PCT/US89/02487 (22) International Filing Date: 7 June 1989 (07.06.89) (30) Priority data: 203,114 7 June 1988 (07.06.88) US (71) Applicant: NOISE CANCELLATION TECHNOLOGIES, INC. [US/US]; 10015 Old Columbia Rd., Ste. F100, Columbia, MD 21046 (US). (72) Inventor: ZIEGLER, Eldon, W., Jr. ; 10092 Hatbrim Terrace, Columbia, MD 21046 (US). (74) Agent: EVENSON, Donald, D.; Barnes & Thornburg, 1815 H Street, Suite 800, Washington, DC 20006 (US).</p>		<p>(81) Designated States: AT (European patent), AU, BE (European patent), BR, CH (European patent), DE (European patent), FR (European patent), GB (European patent), IT (European patent), JP, KR, LU (European patent), NL (European patent), SE (European patent), SU.</p> <p>Published <i>With international search report.</i> <i>Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i></p>
<p>(54) Title: SOUND ATTENUATION SYSTEM FOR PERSONAL SEAT</p> <div data-bbox="581 1033 1286 1667" data-label="Diagram"> </div> <p>(57) Abstract</p> <p>A sound cancellation system wherein a pair of sensors (10, 12) and actuators (14, 16) are positioned immediately adjacent an associated ear of an inhabitant of an enclosure so as to provide a cancellation zone immediately adjacent an associated ear without interfering with adjacent zones. A controller (18) receives a synchronization signal (20) so as to cancel a selected noise associated with a synchronization signal. The sensors (10, 12) and actuators (14, 16) are mounted to a seat which is to be occupied by an inhabitant of the enclosure.</p>		

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SOUND ATTENUATION SYSTEM FOR PERSONAL SEAT

BACKGROUND AND SUMMARY OF THE INVENTION

The present invention relates generally to sound attenuators and more specifically to a sound attenuator for an enclosure.

5 Sound attenuators in the prior art have included passive as well as active attenuators. The providing of sound absorbing material is a well-known passive device. Active sound attenuators have taken two general approaches. The first is to attenuate the sound at its
10 source. This generally includes measuring the sound at its source and producing a cancelling sound 180° out of phase at the source of the sound or noise. The second method is to cancel or attenuate the noise at a location remote from the noise at which inhabitants are expected to
15 occupy.

 Within the second group of active sound attenuators at a remote point from the noise, there have developed two general overall methodologies. In the first methodology, noise are to be attenuated throughout the total
20 enclosure. This generally would include measuring the noise level within the enclosure and providing appropriate cancelling noise to cancel the noise throughout the total enclosure. The less sophisticated systems use a few actuators to produce the cancelling noise where others do
25 a complete study of the total enclosure finding the nodal points of maximum noise and placing the actuators at the maximum nodal point. This second system requires a

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substantial amount of time and research to determine the nodal points. This method and the less sophisticated systems depend on noise produced during a test period. The noise itself may have different nodal points or be noise different from that designed around and therefore the anti-noise or cancelling signal produced by the actuators may not be effective. Also, the cancelling noise may combine with the noise level instead of cancelling and reducing it.

10 In addition to the dynamics of the enclosure, the interaction of the actuators must also be taken into account. This is especially true where the actuators are substantially displaced from the sensors and the actuator must be driven at sufficiently high amplitude. This substantially increases the complexity of the noise patterns within the enclosure.

20 A second methodology of cancelling the noise in an enclosure specifically at the occupant or inhabitant includes placing earphones on the occupant. The earphones not only operate as a passive device for cancelling sound, it may also have actuators and sensors to measure and cancel actively the noise at the ears. These have generally been suggested for use in industrial environments where there are high levels of noise due to machinery or where a headset is naturally worn, for example by pilots.

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In vehicles, which comprise an enclosure, or other space, it is highly desirable to cancel the noise to the occupants produced by known sources of noise, for example, an engine or other periodically occurring noises of the vehicle, without adversely affecting the hearing of the driver/occupant. It is illegal in some states to wear earphones or other devices while driving since it is believed that it impairs the driver and other occupants from hearing emergency vehicles or be aware of other dangerous conditions about them. Thus, cancellation of the noise in the total enclosure has been the general approach to noise attenuation within the interior of the vehicle.

Thus it is an object of the present invention to provide a sound attenuation system which is localized to the inhabitants without the use of earphones.

Another object of the present invention is to provide localized attenuation of sounds in specific sub-zones of an enclosure without interaction of other sounds within the enclosure.

A still further object of the present invention is to provide an inexpensive sound attenuation system and method to provide localized sound attenuation for the inhabitants of an enclosed space at their positions of occupancy.

These and other objects are attained by mounting an acoustic sensor and actuator, at one or more selected locations of an enclosure, spaced from but immediately

adjacent an occupant's ears at the selected location or locations. A synchronization signal is determined for the source of noise and used by a controller in combination with the sensed sounds from the sensor to control the actuator to cancel sounds from the noise source in a zone limited to the inhabitant at the specific selected location without adversely affecting other locations in the enclosure. Preferably, a pair of acoustic sensors and actuators are positioned immediately adjacent each ear of the inhabitant. The controller independently controls the actuators using the synchronization signal and the signal from the associated sensor to cancel the sound from the source of sound in the zone limited to the associated ear. The actuator and sensor should be sufficiently close to the ear to produce a localized zone and prevent interference between the actuators and sensors at each ear of an individual occupant as well as among the various occupants and zones. The sensor should be adjustable so as to be positioned as close as possible to the ear or ears of the occupant to maximize the accuracy of the measurement portion of the system. For the occupant of the vehicle, the sensor and actuator could be mounted to the seat to be occupied by the inhabitant.

Other objects, advantages and novel features of the present invention will become apparent from the following detailed description of the invention when considered in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic view of a noise cancellation system incorporating the principles of the present invention.

5 Figure 2 is a perspective view of a system incorporating the principles of the present invention into a seat of a vehicle.

 Figure 3 is a perspective view of the incorporation of the principles of the present invention into a
10 four-occupant vehicle.

DETAILED DESCRIPTION OF THE INVENTION

A noise cancellation system monitors the sound as close as possible to the inhabitant of an enclosed space
15 at its expected position and provides a cancelling noise immediately adjacent the monitored area in such a manner as to not interfere with other zones or spaces throughout the enclosure. As illustrated in Figure 1, microphones 10 and 12 are placed adjacent respective ears of an occupant
20 and provide sensed input signals to a noise cancellation controller 18. The output of the noise cancellation controller is provided through amplifier 22 to a pair of actuators 14 and 16, and also adjacent associated sensor 10 and 12 and an associated ear of the occupant. A
25 synchronized input signal 20 is also provided to the noise cancellation controller 18 so as to identify and cancel the synchronous noise. This allows cancellation of an

identified noise signal while allowing other sounds to reach the ear of the inhabitant.

The controller 18 can be an NCT-2000, available from Noise Cancellation Technologies, Inc., of Columbia, Maryland. This would use a frequency domain technique as described in U.S. patent 4,490,841 to Chaplin et al. The singular controller can monitor and selectively control the appropriate zone adjacent each ear. Alternatively, a time domain technique may be used in controller 18. The technique used by the controller is not as important as the ability to monitor sound in a small zone and produce a cancelling sound in that zone so as not to interfere with adjacent zones.

The size of the zone of cancellation depends, in part, on the frequency to be cancelled and the complexity of the sound field. In complex sound fields found in small, enclosed, reverberant compartments, the zone of cancellation is formed from spheres centered on each sensor with a radius of approximately $1/10$ of the wavelength of the frequency being cancelled. Thus, for example, in air a zone nearly two feet in radius is produced when cancelling a 60 Hz frequency while a zone of seven inches in radius is produced when cancelling a 200 Hz frequency.

Because of the size of the zones of cancellation, the preferred embodiment utilizes two sensors, one near each location which an inhabitant's ear will be during use.

The farther away the actuators 14 are from the area to be cancelled, the higher the sound level required at each actuator due to attenuation between the actuator and sensor. This increases the interaction between the actuator and the other sensors and therefore creates a more complicated problem as well as increasing sound levels at nearby locations. This will create nodes of cancellation as well as nodes of substantially increased levels.

10 The synchronization signal on line 20 may be from known sources of noise which are to be cancelled. Such noise may be from an engine in an automobile, or other well-known sources of reoccurring noise or vibrations such as alternators or fans.

15 The application of the system of Figure 1 to a vehicle seat is illustrated in Figure 2. The vehicle seat 24 includes the sensors 12 and 14 mounted on a flexible telescoping element 26 which are pivotally mounted on 28 to the seat. This would be equivalent to an antenna construction. The actuators 14 and 16 are mounted in a wrap-around wing of the seat. The structure 26, 28 of the sensor mountings 10, 12 allow adjustment of the sensors 10, 12 to be placed immediately adjacent the ears of the inhabitant of the seat 24. The telescoping flexible section 26 as well as the pivotal mount 28 allows not only adjustment, but movement and deflection, in case movement

of the head of the inhabitant causes contact with the sensors 10 and 12 and therefore no injury will result.

Placing the sensors 10 and 12 as close as possible to the ear of the inhabitant, the most accurate measurement of the noise adjacent the ear is measured. The actuators 14 and 16 are within a foot of the ear of the inhabitant and therefore, their zone of cancellation can be sufficiently small. They are also sufficiently separated from each other zone so as to not interfere with each other. Also, the amplitude of the signals produced by the actuators 14, 16 may be reduced since they are sufficiently close and the zone of cancellation is sufficiently small. By using low level signals from the actuators, the attenuation with distance is sufficiently great that at any zone of interaction, the interaction is minimal.

As illustrated in Figure 3, the front seat of a vehicle may include two cancellation systems 30 and 32 having individual noise cancellation systems, while the back seat includes individual cancellation systems 34, 36. Each noise cancellation system include two pair of sensors and actuators, one adjacent each ear of the inhabitant of the seat. Although being illustrated for a automobile, the present system may be used in the enclosure of any vehicle, for example, trucks, construction equipment or farm equipment, as well as trains, planes and other types of vehicles. Similarly, a

system of this type could be used in any other confined space where an inhabitant could be specifically located so that the sensor and actuator can be positioned as close as possible to the individual ears of the inhabitant such
5 that a low amplitude noise cancellation signal can be applied to minimize and substantially eliminate any interference between the actuators and sensors of adjacent zones.

Although the present invention has been described and
10 illustrated in detail, it is to be clearly understood that the same is by way of illustration and example only, and is not to be taken by way of limitation. The spirit and scope of the present invention are to be limited only by the terms of the appended claims.

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WHAT IS CLAIMED:

1. A method of attenuating selective sounds at a selective location in an enclosure at which an inhabitant is to be positioned comprising:

producing a synchronization signal for a source of noise to be attenuated;

mounting an acoustic sensor and acoustic actuator at a selected location in said enclosure to be spaced from, but immediately adjacent, an inhabitant's ears at said selected location; and

controlling said actuator, using said synchronization signal and sounds sensed by said sensor, to cancel sounds from said source of noise in a zone limited to said inhabitant at said selected location without adversely affecting other locations in said enclosure.

2. A method according to Claim 1, wherein mounting includes mounting a pair of acoustic sensors and actuators at said selected location to be spaced from and immediately adjacent an associated ear of said inhabitant at said selected location.

3. A method according to Claim 2, wherein controlling includes controlling each actuator independently, using its associated sensor and said synchronization signal to cancel sounds from said source of noise in a zone limited to its associated ear.

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4. A method according to Claim 2, including selecting the position of each pair of said sensors and actuators to be within twelve inches of an associated ear of said inhabitant..

5. A method according to Claim 1, including selecting the position of said sensor and actuator to be within twelve inches of an inhabitant's ears.

6. A method according to Claim 1, wherein said mounting includes mounting a sensor and actuator, at each location in said enclosure at which an inhabitant is to be positioned, spaced from but immediately adjacent an associate inhabitant's ears.

7. A method according to Claim 6, wherein said controlling includes controlling each actuator independently, using its associated sensor and said synchronization signal to cancel sounds from said source of noise in a zone limited to its associated inhabitant's ears.

8. A method according to Claim 1, wherein said mounting includes mounting a pair of sensors and actuators, at each location in said enclosure at which an inhabitant is to be positioned, to be spaced from and immediately adjacent an associated ear of said inhabitant at said location.

9. A method according to Claim 8, wherein controlling includes controlling each actuator independently, using its

associated sensor and said synchronization signal to cancel sounds from said source of noise in a zone limited to its associated ear.

10. A system for attenuating selective sounds at a selective location in an enclosure at which an inhabitant is to be positioned comprising:

synchronization means for producing a synchronization signal for a source of noise to be attenuated;

mounting means for mounting an acoustic sensor and acoustic actuator at a selected location in said enclosure to be spaced from but immediately adjacent an inhabitant's ears at said selected location; and

control means for controlling said actuator, using said synchronization signal and sounds sensed by said sensor, to cancel sounds from said source of noise in a zone limited to said inhabitant at said selected location without adversely affecting other locations in said enclosure.

11. An apparatus according to Claim 10, wherein said mounting means includes a pair of mounting means each for mounting a pair of acoustic sensors and actuators at said selected locations to be spaced from and immediately adjacent an associated ear of said inhabitant at said selected location.

12. An apparatus according to Claim 11, wherein said control means controls each actuator independently, using its associated

sensor and said synchronization signal to cancel sounds from said source of noise in a zone limited to its associated ear.

13. An apparatus according to Claim 11, wherein said mounting means positions each pair of said sensors and actuators to be within twelve inches of an associated ear of said inhabitant.

14. An apparatus according to Claim 13, wherein said mounting means positions each pair of said sensor and actuator to be spaced from each other by at least twice the distance they are separated from an associated ear.

15. An apparatus according to Claim 10, wherein said mounting means positions said sensor and actuator to be within twelve inches of an inhabitant's ears.

16. An apparatus according to Claim 10, wherein said mounting means includes a plurality of mounting means for mounting a sensor and actuator, at each location in said enclosure at which an inhabitant is to be positioned, spaced from but immediately adjacent an associated inhabitant's ears.

17. An apparatus according to Claim 16, wherein said control means controls each actuator independently, using its associated sensor and said synchronization signal to cancel sounds from said source of noise in a zone limited to its associated inhabitant's ears.

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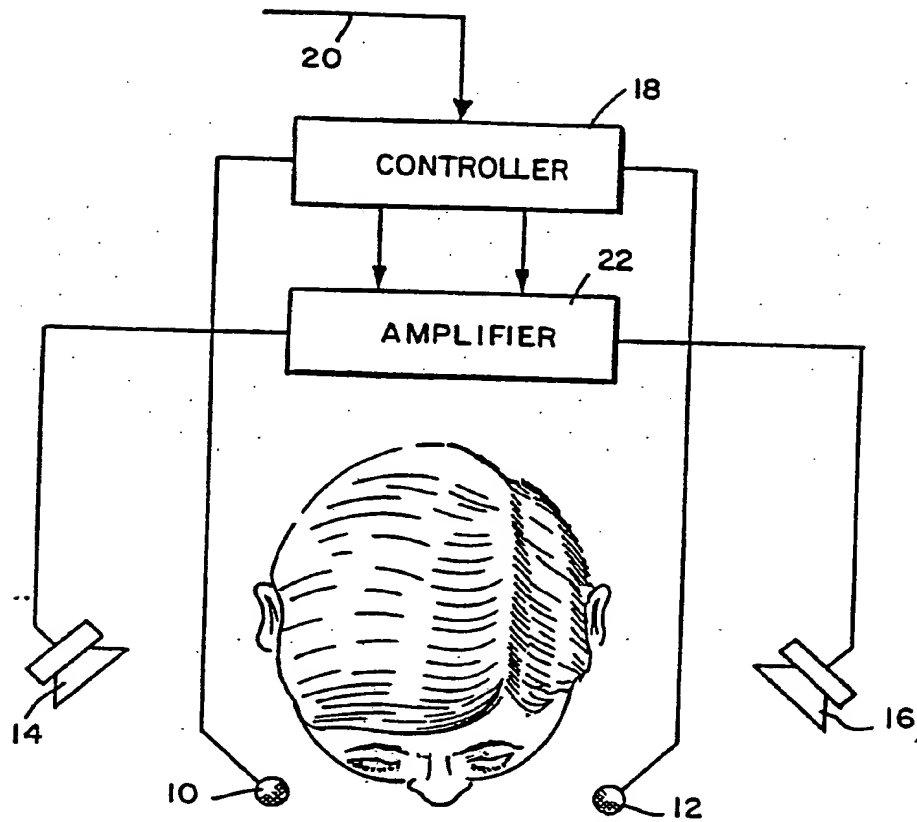
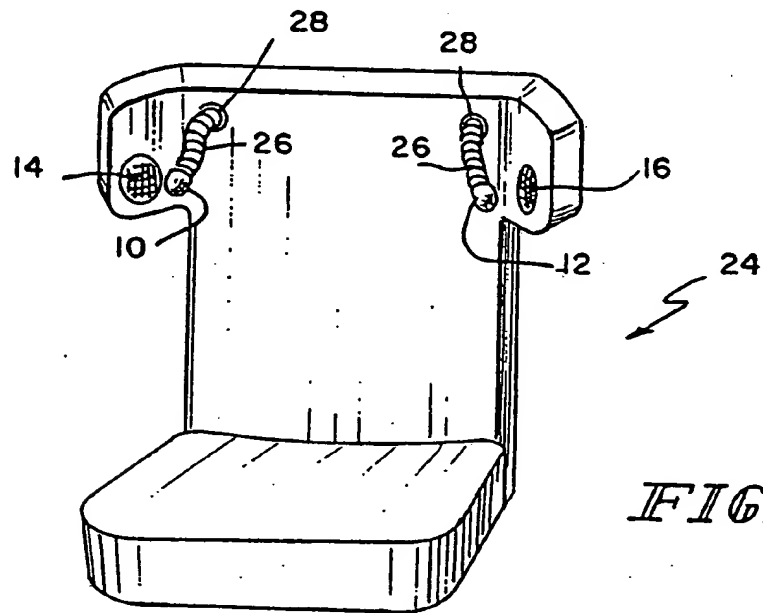
18. An apparatus according to Claim 10, wherein said mounting means includes a plurality of mounting means each for mounting a pair of sensors and actuators, at each location in said enclosure at which an inhabitant is to be positioned, to be spaced from and immediately adjacent an associated ear of said inhabitant at said location.

19. An apparatus according to Claim 18, wherein said control means controls each actuator independently, using its associated sensor and said synchronization signal to cancel sounds from said source of noise in a zone limited to its associated ear.

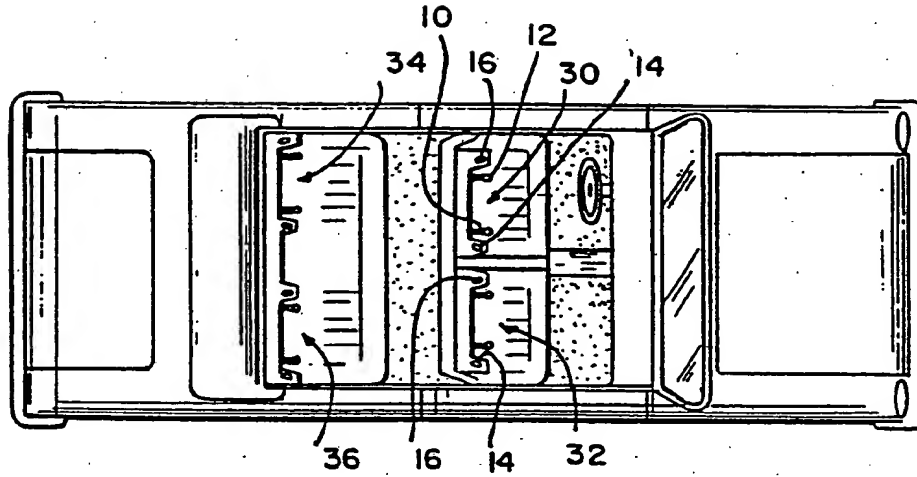
20. An apparatus according to Claim 10, wherein said mounting means includes adjustment means for adjusting said sensor with respect to an inhabitant at said selected location.

21. An apparatus according to Claim 10, wherein said mounting means mounts said sensor and actuator to a portion of a seat, at said selected location, to be immediately adjacent an inhabitant's ears when it occupies said seat.

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*FIG. 1**FIG. 2*

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*FIG. 3*

INTERNATIONAL SEARCH REPORT

International Application No. PCT/US 89/02487

I. CLASSIFICATION OF SUBJECT MATTER (If several classification symbols apply, indicate all) ⁶ According to International Patent Classification (IPC) or to both National Classification and IPC INT. CL. ⁷ A 61 F 11/02 US. CL. 381/72																	
II. FIELDS SEARCHED <div style="text-align: center; margin-top: 10px;">Minimum Documentation Searched ⁷</div> <table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 30%; padding: 5px;">Classification System</td> <td style="padding: 5px;">Classification Symbols</td> </tr> <tr> <td style="padding: 5px;">U.S.</td> <td style="padding: 5px;">381/ 71, 72, 94</td> </tr> </table> <div style="text-align: center; margin-top: 10px;">Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched ⁸.</div> <div style="padding: 5px; margin-top: 10px;">NONE</div>			Classification System	Classification Symbols	U.S.	381/ 71, 72, 94											
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III. DOCUMENTS CONSIDERED TO BE RELEVANT ⁹ <table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <th style="width: 10%; padding: 5px;">Category ⁹</th> <th style="width: 70%; padding: 5px;">Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²</th> <th style="width: 20%; padding: 5px;">Relevant to Claim No. ¹³</th> </tr> <tr> <td style="text-align: center; padding: 5px;">Y</td> <td style="padding: 5px;">US, A, 4,506,380 (MATSUI) 19 March 1985. See Figure 5 and column 3, lines 22-66.</td> <td style="text-align: center; padding: 5px;">1-21</td> </tr> <tr> <td style="text-align: center; padding: 5px;">Y</td> <td style="padding: 5px;">US, A, 4,654,871 (CHAPLIN ET AL) 31 March 1987. See Figure 1 and column 1, line 54 to column 2, line 68.</td> <td style="text-align: center; padding: 5px;">1-21</td> </tr> <tr> <td style="text-align: center; padding: 5px;">Y</td> <td style="padding: 5px;">FR, A, 2,550, 903 (ALBARAZIN ET AL) 22 February 1985. See Figure 2 and Abstract.</td> <td style="text-align: center; padding: 5px;">1-21</td> </tr> <tr> <td style="text-align: center; padding: 5px;">Y</td> <td style="padding: 5px;">John Free, "Noise Zapper", Popular Science, January 1987, pp. 76, 77, 96. See Figure on page 77.</td> <td style="text-align: center; padding: 5px;">1-21</td> </tr> </table>			Category ⁹	Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²	Relevant to Claim No. ¹³	Y	US, A, 4,506,380 (MATSUI) 19 March 1985. See Figure 5 and column 3, lines 22-66.	1-21	Y	US, A, 4,654,871 (CHAPLIN ET AL) 31 March 1987. See Figure 1 and column 1, line 54 to column 2, line 68.	1-21	Y	FR, A, 2,550, 903 (ALBARAZIN ET AL) 22 February 1985. See Figure 2 and Abstract.	1-21	Y	John Free, "Noise Zapper", Popular Science, January 1987, pp. 76, 77, 96. See Figure on page 77.	1-21
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IV. CERTIFICATION <table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 50%; padding: 5px;"> Date of the Actual Completion of the International Search 02 October 1989 </td> <td style="width: 50%; padding: 5px;"> Date of Mailing of this International Search Report <div style="font-size: 1.2em; font-weight: bold;">25 OCT 1989</div> </td> </tr> <tr> <td style="padding: 5px;"> International Searching Authority ISA/US </td> <td style="padding: 5px;"> Signature of Authorized Officer <div style="text-align: center;"> F. W. ISEN-PRIMARY EXAMINER </div> </td> </tr> </table>			Date of the Actual Completion of the International Search 02 October 1989	Date of Mailing of this International Search Report <div style="font-size: 1.2em; font-weight: bold;">25 OCT 1989</div>	International Searching Authority ISA/US	Signature of Authorized Officer <div style="text-align: center;"> F. W. ISEN-PRIMARY EXAMINER </div>											
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